II. *The true Theory of the Tides, extracted from that admired Treatiſe of* Mr. Iſaac Newton, *Intituled,* Philoſophiæ Naturalis Principia Mathematica; *being a Diſcourſe preſented with that Book to the late King* James, *by* Mr. Edmund Halley.

IT may, perhaps, ſeem ſtrange, that this Paper, being no other than a partile Account of a Book long ſince publiſhed, and whereof a fuller Extract was given in Numb. 187. *of theſe Tranſactions, ſhould again appear here; but the Deſires of ſeveral honourable Perſons, which could not be withſtood, have obliged us to inſert it here, for the ſake of ſuch, who being leſs knowing in Mathematical Matters; and therefore, not daring to adventure on the Author himſelf, are notwithſtanding, very curious to be informed of the Cauſes of Things; particularly of ſo general and extraordinary* Phænomena, *as are thoſe of the Tides. Now this Paper having been drawn up for the late King* James's *Uſe, (in whoſe Reign the Book was publiſhed) and having given good Satisfaction to thoſe that got Copies of it; it is hoped the Savans of the higher Form will indulge us this liberty we take to gratifie their Inferiours in point of Science; and not be offended, that we here inſiſt more largely upon Mr.* Newton's Theory of the Tides, *which, how plain and eaſie ſoever we find, is very little underſtood by the common Reader.*

The ſole Principle upon which this Author proceeds to explain moſt of the great and ſurpriſing Appearances of Nature, is no other than that of *Gravity*, whereby in the Earth all Bodies have a tendency towards its Centre;

as is moſt evident: and from undoubted Arguments its proved, that there is ſuch a Gravitation towards the Centre of the Sun, Moon, and all the Planets.

From this Principle, as a neceſſary Conſequence, follows the Sphærical Figure of the Earth and Sea, and of all the other Cæleſtial Bodies: and tho' the tenacity and firmneſs of the Solid Parts, ſupport the Inequalities of the Land above the Level; yet the Fluids, preſſing equally and eaſily yielding to each other, ſoon reſtore the *Æquilibrium*, if diſturbed, and maintain the exact Figure of the Globe.

Now this force of Deſcent of Bodies towards the Center, is not in all places alike, but is ſtill leſs and leſs, as the diſtance of the Center encreaſes: and in this Book it is demonſtrated, that this Force decreaſes as the Square of the diſtance increaſes; that is, the weight of Bodies and the force of their Fall is leſs, in parts more removed from the Center, in the proportion of the Squares of the Diſtance. So as for Example, a Ton weight on the Surface of the Earth, if it were raiſed to the height of 4000 Miles, which I ſuppoſe the ſemidiameter of the Earth, would weigh but $\frac{1}{4}$ of a Ton, or 5 Hundred weight: if to 12000 Miles, or 3 ſemidiameters from the Surface, that is 4 from the Center, it would weigh but $\frac{1}{16}$ part of the Weight on the Surface, or a Hundred and Quarter: So that it would be as eaſie for the Strength of a Man at that height to carry a Ton weight, as here on the Surface a 100 $\frac{1}{4}$. And in the ſame Proportion does the Velocities of the fall of Bodies decreaſe: For whereas on the Surface of the Earth all things fall 16 Foot in a ſecond, at one ſemidiameter above this Fall is but 4 Foot; and at 3 ſemidiameters, or 4 from the Centre, it is but $\frac{1}{16}$ of the Fall at the Surface, or but one Foot in a ſecond: And at greater Diſtances both Weight and Fall become very

ſmall,

ſmall, but yet at all given Diſtances is ſtill ſome thing, tho' the Effect become inſenſible. At the diſtance of the Moon (which I will ſuppoſe 60 Semidiameters of the Earth) 3600 Pounds weigh but one Pound, and the fall of Bodies is but $\frac{15}{3600}$ of a Foot in a ſecond, or 16 Foot in a minute; that is, a Body ſo far off deſcends in a Minute no more than the ſame at the Surface of the Earth would do in a Second of Time.

As was ſaid before, the ſame force decreaſing after the ſame manner is evidently found in the Sun, Moon, and all the Planets; but more eſpecially in the Sun, whoſe Force is prodigious; becoming ſenſible even in the immenſe diſtance of *Saturn:* This gives room to ſuſpect, that the force of Gravity is in the Celeſtial Globes proportional to the quantity of Matter in each of them: And the Sun being at leaſt ten Thouſand times as big as the Earth, its Gravitation or attracting Force, is found to be at leaſt ten Thouſand times as much as that of the Earth, acting on Bodies at the ſame diſtances.

This Law of the decreaſe of Gravity being demonſtratively proved, and put paſt contradiction; the Author with great Sagacity, inquires into the neceſſary Conſequences of this Suppoſition; whereby he finds the genuine Cauſe of the ſeveral Appearances in the Theory of the Moon and Planets, and diſcovers the hitherto unknown Laws of the Motion of Comets, and of the Ebbing and Flowing of the Sea. Each of which are Subjects that have hitherto taken up much larger Volumes; but Truth being uniform, and always the ſame, it is admirable to obſerve how eaſily we are enabled to make out very abſtruſe *and difficult Matters,* when once true and genuine Principles are obtained: And on the other hand it may be wondred, that, notwithſtanding the great facility of truth, and the perplexity and nonconſequences that always attend erroneous Suppoſitions, theſe

great Diſcoveries ſhould have eſcaped the acute Diſquiſitions of the beſt Philoſophical Heads of all paſt Ages, and be reſerved to theſe our Times. But that wonder will ſoon ceaſe, if it be conſidered how great Improvements Geometry has received in our Memory, and particularly from the profound Diſcoveries of our incomparable Author.

The Theory of the Motion of the primary *Planets* is here ſhewn to be nothing elſe, but the contemplation of the Curve Lines which Bodies caſt with a given Velocity, in a given Direction, and at the ſame time drawn towards the Sun by its gravitating Power, would deſcribe. Or, which is all one, that the Orbs of the Planets are ſuch Curve Lines as a Shot from a Gun deſcribes in the Air, being caſt according to the direction of the Piece, but bent into a crooked Line by the ſupervening Tendency towards the Earths Centre: And the Planets being ſuppoſed to be projected with a given Force, and attracted towards the Sun, after the aforeſaid manner, are here proved to deſcribe ſuch Figures, as anſwer punctually to all that the Induſtry of this and the laſt Age has obſerved in the Planetary Motions. So that it appears, that there is no need of ſolid Orbs and Intelligences, as the Ancients imagined, nor yet of *Vortices* or Whirlpools of the Celeſtial Matter, as *Des Cartes* ſuppoſes; but the whole Affair is ſimply and mechanically performed, upon the ſole Suppoſition of a Gravitation towards the Sun; which cannot be denied.

The Motion of *Comets* is here ſhewn to be compounded of the ſame Elements, and not to differ from Planets, but in their greater ſwiftneſs, whereby overpowering the Gravity that ſhould hold them to the Sun, as it doth the Planets, they flie off again, and diſtance themſelves from the Sun and Earth, ſo that they ſoon are out of our ſight. And the imperfect Accounts and

Obſer-

Obſervations Antiquity has left us, are not ſufficient to determine whether the ſame Comet ever return again. But this Author has ſhewn how Geometrically to determine the Orb of a Comet from Obſervations, and to find his diſtance from the Earth and Sun, which was never before done.

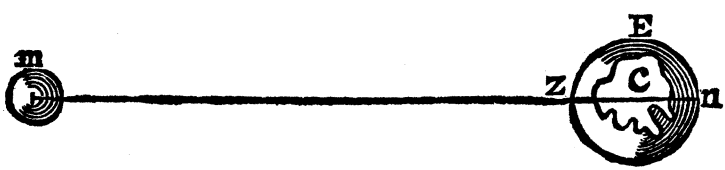
The third thing here done is the Theory of the Moon, all the Inequalities of whoſe Motion are proved to ariſe from the ſame Principles, only here the effect of two Centers operating on, or attracting a projected Body comes to be conſidered; for the Moon, tho' principally attracted by the Earth, and moving round it, does, together with the Earth, move round the Sun once a Year, and is according as ſhe is, nearer or farther from the Sun, drawn by him more or leſs than the Center of the Earth, about which ſhe moves; whence ariſe ſeveral Irregularities in her Motion, of all which, the Author in this Book, with no leſs Subtility than Induſtry, has given a full Account. And tho' by reaſon of the great Complication of the Problem, he has not yet been able to make it purely Geometrical, 'tis to be hoped, that in ſome farther Eſſay he may ſurmount the difficulty: and having perfected the Theory of the Moon, the long deſired diſcovery of the Longitude (which at Sea is only practicable this way) may at length be brought to light, to the great Honour of your Majeſty and Advantage of your Subjects.

All the ſurprizing Phenomena of the Flux and Reflux of the Sea, are in like manner ſhewn to proceed from the ſame Principle; which I deſign more largely to inſiſt on, ſince the Matter of Fact is in this caſe much better known to your Majeſty than in the foregoing.

If the Earth were alone, that is to ſay, not affected by the Actions of the Sun and Moon, it is not to be doubted, but the Ocean, being equally preſſed by the force

force of Gravity towards the Center, would continue in a perfect ſtagnation, always at the ſame height, without ever Ebbing or Flowing; but it being here demonſtrated, that the Sun and Moon have a like Principle of Gravitation towards their Centers, and that the Earth is within the Activity of their Attractions, it will plainly follow, that the Equality of the preſſure of Gravity towards the Center will thereby be diſturbed; and tho' the ſmallneſs of theſe Forces, in reſpect of the Gravitation towards the Earths Center, renders them altogether imperceptible by any Experiments we can deviſe, yet the Ocean being fluid and yielding to the leaſt force, by its riſing ſhews where it is leſs preſt, and where it is more preſt by its ſinking.

Now if we ſuppoſe the force of the Moons attraction to decreaſe as the Square of the Diſtance from its Center increaſes (as in the Earth and other Celeſtial Bodies) we ſhall find, that where the Moon is perpendicularly either above or below the Horizon, either in Zenith or Nadir, there the force of Gravity is moſt of all diminiſhed, and conſequently that there the Ocean muſt neceſſarily ſwell by the coming in of the Water from thoſe parts where the Preſſure is greateſt, *viz.* in thoſe places where the Moon is near the Horizon: but that this may be the better underſtood, I thought it needful to add the following Figure, where *M* is the Moon, *E* the Earth, *C* its Centre, and *Z* the place where the Moon is in the Zenith, *N* where in the Nadir.



Now

Now by the Hypotheſis it is evident, that the Water in *Z*, being nearer, is more drawn by the Moon, than the Center of the Earth *C*, and that again more tha the Water in *N*, wherefore the Water in *Z* has a tendency towards the Moon, contrary to that of Gravity, being equal to the Exceſs of the Gravitation in *Z*. above that in *C*: And in the other caſe, the Water in *N*, tending leſs towards the Moon than the Center *C*, will be leſs preſſed, by as much as is the difference of the Gravitations towards the Moon in *C* and *N*. This rightly underſtood, it follows plainly, that the Sea, which otherwiſe would be Spherical, upon the Preſſure of the Moon, muſt form it ſelf into a Spheroidal or Oval Figure, whoſe longeſt Diameter is where the Moon is Vertical, and ſhorteſt where ſhe is in the Horizon; and that the Moon ſhifting her Poſition as ſhe turns round the Earth once a day, this Oval of Water ſhifts with her, occaſioning thereby the two Floods and Ebbs obſervable in each 25 Hours.

And this may ſuffice as to the general Cauſe of the Tides; it remains now to ſhew how naturally this Motion accounts for all the Particulars that has been obſerved about them; ſo that there can be no room left to doubt, but that this is the true cauſe thereof.

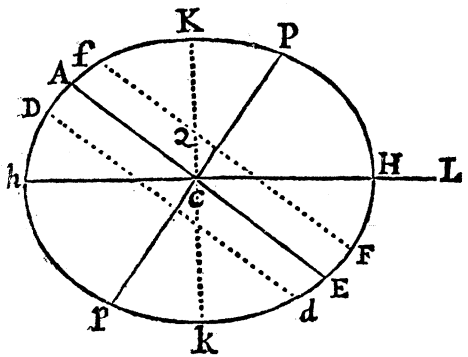
The Spring Tides upon the new and full Moons, and Neap Tides on the Quarters, are occaſioned by the attractive Force of the Sun in the New and Full, conſpiring with the Attraction of the Moon, and producing a Tide by their united Forces: Whereas in the Quarters, the Sun raiſes the Water where the Moon depreſſes it, and the contrary; ſo as the Tides are made only by the difference of their Attractions. That the force of the Sun is no greater in this caſe, proceeds from the very ſmall Proportion the Semidiameter of the Earth bears to the vaſt diſtance of the Sun.

It is alſo obſerved, that *cæteris paribus*, the Æquinoctial Spring Tides in *March* and *September*, or near them, are the Higheſt, and the Neap Tides the Loweſt; which proceeds from the greater Agitation of the Waters, when the fluid *Sphæroid* reſolves about a great Circle of the Earth, than when it turns about in a leſſer Circle; it being plain, that if the Moon were conſtituted in the Pole and there ſtood, that the Sphæroid would have a fixt Poſition, and that it would be always high Water under the Poles, and low Water every where under the Æquinoctial: and therefore the nearer the Moon approaches the Poles, the leſs is the agitation of the Ocean, which is of all the greateſt, when the Moon is in the Æquinoctial, or fartheſt diſtant from the Poles. Whence the Sun and Moon, being either conjoyned or oppoſite in the Æquinoctial, produce the greateſt Spring Tides; and the ſubſequent Neap Tides, being produced by the Tropical Moon in the Quarters, are always the leaſt Tides; whereas in *June* and *December*, the Spring Tides are made by the Tropical Sun and Moon, and therefore leſs vigorous; and the Neap Tides by the Æquinoctial Moon, which therefore are the ſtronger: Hence it happens, that the difference between the Spring and Neap Tides in theſe Months, is much leſs conſiderable than in *March* and *September*. And the reaſon why the very higheſt Spring Tides are found to be rather before the Vernal and after the Autumnal Equinox, *viz.* in *February* and *October*, than preciſely upon them, is, becauſe the Sun is nearer the Earth in the Winter Months, and ſo comes to have a greater Effect in producing the Tides.

Hitherto we have conſidered ſuch Affections of the Tides as are Univerſal, without relation to particular Caſes; what follows from the differing Latitudes of places, will be eaſily underſtood by the following Figure.

Let

Let *A p E P* be the Earth covered over with very deep Waters, *C* its Center, *P*, *p*, its Poles, *A E* the Æquinoctial, *F f* the parallel of Latitude of a place, *D d* another Parallel at equal diſtance on the other ſide of the Æquinoctial, *H h* the two Points where the Moon is vertical, and let *K k* be the great Circle, wherein the Moon appears Horizontal. It is evident, that a Spheroid deſcribed upon *H h*, and *K k* ſhall nearly repre-



ſent the Figure of the Sea, and *C f*, *C D*, *C F*, *C d* ſhall be the hights of the Sea in the places *f*, *D*, *F*, *d*, in all which it is High-water: and ſeeing that in twelve Hours time, by the diurnal Rotation of the Earth, the point *F* is transferred to *f*, and *d* to *D*: the hight of the Sea *C F* will be that of the High-water when the Moon is preſent, and *C f* that of the other High water, when the Moon is under the Earth: which in the caſe of this Figure is leſs than the former *C F*. And in the oppoſite Parallel *D d* the contrary happens. The Riſing of the Water being always alternately greater and leſs in each place, when it is produced by the Moon declining ſenſibly from the Æquinoctial; that being the greateſt of the two High-waters in each diurnal Revolution of

the Moon, wherein ſhe approaches neareſt either to the Zenith or Nadir of the place: whence it is that the Moon in the Northern Signs, in this part of the World, makes the greateſt Tides when above the Earth, and in Southern Signs, when under the Earth; the Effect being always the greateſt where the Moon is fartheſt from the Horizon, either above or below it. And this alternate increaſe and decreaſe of the Tides has been obſerved to hold true on the Coaſt of *England*, at *Briſtol* by Capt. *Sturmy*, and at *Plymouth* by Mr. *Colepreſſe*.

But the Motions hitherto mentioned are ſomewhat altered by the Libration of the Water, whereby, tho' the Action of the *Luminaries* ſhould ceaſe, the Flux and Reflux of the Sea would for ſome time continue: This Conſervation of the impreſſed Motion diminiſhes the differences that otherwiſe would be between two conſequent Tides, and is the reaſon why the higheſt Spring Tides are not preciſely on the new and full Moons, nor the Neaps on the Quarters; but generally they are the third Tides after them, and ſometimes later.

All theſe things would regularly come to paſs, if the whole Earth were covered with Sea very deep; but by reaſon of the ſhoalneſs of ſome places, and the narrowneſs of the Streights, by which the Tides are in many caſes propagated, there ariſes a great diverſity in the Effect, and not to be accounted for, without an exact Knowledge of all the Circumſtances of the Places, as of the Poſition of the Land, and the Breadth and Depth of the Channels by which the Tide flows; for a very ſlow and imperceptible Motion of the whole Body of the Water, where it is (for example) 2 Miles deep, will ſuffice to raiſe its Surface 10 or 12 Feet in a Tides time; whereas, if the ſame quantity of Water were to be conveyed upon a Channel of 40 Fathoms deep, it would

would require a very great Stream to effect it, in ſo large Inlets as are the Channel of *England* and the *German* Ocean; whence the Tide is found to ſet ſtrongeſt in thoſe places where the Sea grows narroweſt; the ſame quantity of Water being to paſs through a ſmaller Paſſage: This is moſt evident in the *Streights*, between *Portland* and *Cape de Hague* in *Normandy*, where the Tide runs like a Sluce; and would be yet more between *Dover* and *Calis*, if the Tide coming about the Iſland from the North did not check it. And this force being once impreſſed upon the Water, continues to carry it about the level of the ordinary height in the Ocean, particularly where the Water meets a direct Obſtacle, as it is at St. *Malo's*; and where it enters into a long Channel, which running far into the Land, grows very ſtreight at its Extremity; as it is in the *Severn-Sea* at *Chepſtow* and *Briſtol*.

This ſhoalneſs of the Sea and the intercurrent Continents are the reaſon, that in the open Ocean the time of High-water is not at the Moons appulſe to the Meridian, but always ſome Hours after it; as it is obſerved upon all the Weſt-Coaſt of *Europe* and *Africa*, from *Ireland* to the *Cape of Good-Hope*: In all which a S. W. Moon makes High-water, and the ſame is reported to be on the Weſt ſide of *America*. But it would be endleſs to account all the particular Solutions, which are eaſie Corollaries of this *Hypotheſis*; as why the *Lakes*, ſuch as the *Caſpian Sea*, and *Mediterranian Seas*, ſuch as the *Black Sea*, the *Streights* and *Baltick*, have no ſenſible Tides: For *Lakes* having no Communication with the Ocean, can neither increaſe nor diminiſh their Water, whereby to riſe and fall; and Seas that communicate by ſuch narrow Inlets, and are of ſo immenſe an Extent, cannot in a few Hours time receive or empty Water enough to raiſe or ſink their Surface any thing ſenſibly.

Laſtly, to demonſtrate the excellency of this Doctrine, the Example of the Tides in the Port of *Tunking* in *China*, which are ſo extraordinary, and differing from all others we have yet heard of, may ſuffice. In this Port there is but one Flood and Ebb in 24 Hours; and twice in each Month, *viz.* when the Moon is near the Æquinoctial there is no Tide at all, but the Water is ſtagnant; but with the Moons declination there begins a Tide, which is greateſt when ſhe is in the Tropical Signs: only with this difference, that when the Moon is to the Northward of the Æquinoctial, it Flows when ſhe is above the Earth, and Ebbs when ſhe is under, ſo as to make High-water at Moons-ſetting, and Low-water at Moons-riſing: But on the contrary, the Moon being to the Southward, makes High-water at riſing and Low-water at ſetting; it Ebbing all the time ſhe is above the Horizon. As may be ſeen more at large in the *Philoſophical Tranſaction*, Num. 162.

The Cauſe of this odd Appearance is propoſed by *Mr. Newton*, to be from the concurrence of two Tides; the one propagated in ſix Hours out of the great *South-Sea* along the Coaſt of *China*; the other out of the *Indian-Sea*, from between the Iſlands in twelve Hours, along the Coaſt of *Malacca* and *Cambodia*. The one of theſe Tides, being produced in North-Latitude, is, as has been ſaid, greater, when the Moon being to the North of the Equator is above the Earth, and leſs when ſhe is under the Earth. The other of them, which is propagated from the *Indian-Sea*, being raiſed in South Latitude, is greater when the Moon declining to the South is above the Earth, and leſs when ſhe is under the Earth: So that of theſe Tides alternately greater and leſſer, there comes always ſucceſſively two of the greater and two of the leſſer together every day; and the High-water falls always between the times of the arri-

val.

val of the two greater Floods; and the Low-water between the arrival of the two leſſer Floods. And the Moon coming to the Æquinoctial, and the alternate Floods becoming equal, the Tide ceaſes and the Water ſtagnates: but when ſhe has paſſed to the other ſide of the Equator, thoſe Floods which in the former Order were the leaſt, now becoming the greateſt, that that before was the time of High-water now becomes the Low-water, and the Converſe. So that the whole appearance of theſe ſtrange Tides, is without any forcing naturally deduced from theſe Principles, and is a great Argument of the certainty of the whole *Theory*.

III. *An Account of a Child Born alive without a Brain, and the Obſervables in it on Diſſection, by Dr.* Charles Preſton.

SIR,

IN obedience to your Commands, and judging it will not be unacceptable, I have Collected the beſt Account (in ſo far as I can remember) of that extraordinary Birth, mentioned in the fourth Journal of the *Progres de la Medicine*, for the Month of *April*, 1695. of which I had the fortune to be a Witneſs, and alſo the opportunity of examining more particularly: But in the firſt place, I think it not amiſs to relate the Story as it is given in by *Monſieur Le Duc*, ſworn Chirurgeon of *Paris*, famous for his Practice in Midwifery; and I hereafter ſhall proceed to give a farther Hiſtory of the thing, with all the Circumſtances about it, and ſhow wherein they are in a Miſtake.

April